Methodologies and Tools to Improve Spatial Ability

Article *in* Procedia - Social and Behavioral Sciences · December 2012

DOI: 10.1016/j.sbspro.2012.08.233

Melchor Garcia
Universidad de Las Palmas de Gran Canaria

Jorge Martin-Gutierrez
Universidad de La Laguna

Available online at www.sciencedirect.com
SciVerse ScienceDirect
Procedia - Social and Behavioral Sciences 51 (2012) 736 – 744
Procedia
Social and Behavioral Sciences

ARTSEDU 2012

Methodologies and tools to improve spatial ability

Melchor García Domínguez[a], Jorge Martín-Gutiérrez[b*], Cristina Roca González[a], Carmen M. Mato Corredeaguas[c]

[a]*Universidad de Las Palmas de Gran Canaria, Campus Universitario de Tafira, Las Palmas de Gran Canaria, 35017, Spain*
[b]*Universidad de La Laguna, Av.Astrofísico Fco Sánchez, sn. La Laguna-Tenerife, 38206, Spain*
[c]*Universidad de Las Palmas de Gran Canaria, Santa Juana de Arco, nº 1, Las Palmas de Gran Canaria, 35004, Spain*

Abstract

In the actual curriculums of engineering degrees in the framework of the European Higher Education Area (EHEA), the spatial vision skill is considered as a competence that should be developed by students. The teachers of Graphic Design are struggling to achieve that students develop those tasks which require spatial visualization and reasoning abilities. This is the source of interest for developing and validating applications and procedures which might be included in the curriculum of Graphic Engineering for providing the students with good levels of spatial skill. This paper presents a satisfaction study about the tools and didactic material designed to evaluate the effect of attending several intensive remedial courses based on three different methodologies: Virtual Reality (VR), Augmented Reality (AR) and Portable Document Format 3D (PDF3D) intended to improve the spatial ability of freshmen engineering students.

Keywords: Spatial abilities; Augmented Reality; Virtual Reality; Engineering Education

1. Background

The subjects of Graphic Design in Engineering had traditionally a common main aim: teaching all sketching techniques of 3D reality in a 2D surface (paper) to students from different kinds of engineering degrees. These techniques are sketching systems.

The engineer's work is developed in environments which always have in common the characteristic of being part of that 3D reality (a car, a building, etc) that traditionally has been designed and sketched through those two-dimensional methods. So it's quite important for these professionals having good levels of three-dimensional vision as it has been clearly stated in several studies (Sorby, 1999;Rafi, Samsudin, & Said, 2008; Martín-Gutiérrez et al, 2010),which have underlined the importance of that competences in spatial abilities (SA) understood as the cognitive abilities which belongs to the spatial factor or spatial capability for graduates in engineering degrees.

The adequate development of these abilities is directly linked to future success if his professional performance (Miller, 1996;Adánez and Velasco, 2002), That's why these competences are part of the generic o transverse competences in all degrees belonging to the engineering field.

* Corresponding author. Tel.: +34-922-319-871; fax: +34-922-319-870.
E-mail address: jmargu@ull.edu.es

1877-0428 © 2012 Published by Elsevier Ltd. Selection and/or peer review under responsibility of Prof. Ayşe Çakır İlhan
doi:10.1016/j.sbspro.2012.08.233

These abilities, as several others from the human being can be taught, as human beings have the ability to learn and improving the levels of knowledge and skill which we have in each moment. In the last decade, the spatial ability and its development in humans has been widely investigated and studied for development of new technologies, methodologies and learning tools always looking for improvement of the student's spatial understanding skills.

In the last few years there has been an important evolution about teaching of Graphic Design in technical degrees. New technologies incoming have been fundamental in this evolution conditioning deeply the teaching and learning process of this subject.

Besides, the steep rise of students in engineering degrees is starting to make those traditional strategies look outdated while using physical models where student can manipulate those models with his hands, turning it until understanding it being able to develop plan for sketching it. This fact, make us plan methodologies for disregarding physical models besides motivating the students about learning with new computer technologies they are familiar with. We developed a Drawing Support System (SAD) which is a standard HTML web tool that allows handling virtual models (virtual reality). The augmented reality technology is in full development in the learning environment, in fact, the Horizon report points out that during the next three years there will be a huge peak of this technology in education. It's outstanding the simplicity of use and potential of the 'Portable Document Format 3D' for creating didactic materials so we use this technologies for developing new versions of the didactic material created with SAD.

2. Proposal technologies

In this context, we have performed an experience with three different technologies: virtual reality (VR), augmented reality (AR) and Portable Document format (PDF3D), for comparing them and deciding which methodology is the most suitable from the student's perspective for understanding the aspects of that 3D reality.

2.1. Virtual reality (VR)

This is how the set of technologies and interfaces which allow one or more users to interact in real time with a computer-generated 3D environment or dynamic world is called. These 3D elements and interactive environments are built through VRML language which has evolved through different versions since its beginning in 1994.

The continuous improvement of tools allowing creation of Virtual reality applications and the better performance of the technology equipment needed for executing them have made them become an standard in the training processes of spatial ability.

For building scenes and worlds through VRML, the lowest level programming can be used as a resource, as well as the syntax and semantics of language where an ISO spec of language exists and a big amount of bibliography too. In our case, for development of this virtual world we have used 3D design programs and their VRML export abilities.

2.2. Augmented reality (AR)

This is the term used for defining the direct or indirect vision of a physical environment from the real world, which elements combine with virtual elements for creating a mixed reality on real time. It consists on a set of devices which add virtual information to the physical info that already exists. This is the main difference with Virtual reality as it doesn't replace the physical reality but over impose the computer data over the real world.

2.3. Portable Document Format 3D (PDF3D)

The PDF format has incorporated the 3D object vision capability inside its multimedia characteristics through the Universal 3D (U3D) format included in its PRO X version. The portable document format (PDF) developed by Adobe Systems has become the information exchange standard from any application or computer system. It has the following characteristics:

- **Open standard:** the PDF format is an open standard developed under the ISO 32000 norm.

- **Multiplatform**: the PDF files may be visualized on every platform available including Windows®, Mac OS and mobile platforms such as Android™.
- **Extendable**: Many providers offer PDF based solutions including creation, plug-ins, consultancies and technical support tools.
- **Reliable and secure**: the fact that there is over 150 millions of PDF documents available for public use online together with the huge amount of PDF files available in both public and business administration proves that enterprises trust format for information transmission.
- **Sophistication for information's integrity**: the PDF files have the same aspect and show the same information as the original files like text, drawings, multimedia content, videos, 3D, maps, colorgraphics and pictures regardless of the application used for creating them or being compiled in a unique PDF folder from several formats.
- **Search capability**: the text search tools on documents and metadata ease searching over PDF files.
- **Accessibility**: the PDF files use support technologies for easing the access to information for people with disabilities.
- **Interactive**: Its new 3D manipulation capability (U3D) has made it become one of the best systems for distributing and sharing graphic information.

3. Justification

In the academic environment, the Graphic Design teachers usually find students who have difficulties for solving those tasks requiring spatial reasoning and viewing abilities. In the curriculums of degrees where the Graphic Design subject appears (previous to EEES change), doesn't make any reference about providing a development for student's spatial ability acquisition. As time available for developing the contents of the subject is short, the teachers do not consider how a student may be able to develop the mental abilities of objects' rotation, spatial reasoning ,etc.

There is a void in the curriculums of Graphic Design programs with regard to providing students with spatial ability which in case of being covered, could achieve that those students with bigger difficulties for understanding the sketching systems may be able to overcome that difficulty.

Each one of those technologies (VR, AR Y PDF3D) has been applied successfully in the learning processes of technological subjects in university degrees for noticing the students lacking spatial abilities.

The actual curriculums of engineering field degrees, in the framework of the European Space for Higher Education (ESHE), the spatial vision capability is present as a competence that should be developed by students in the basic formation of all engineering degrees. Here rises the interest for developing and validating applications which may be included in the curriculum of the Engineering Graphic subject for providing the students with good levels of spatial ability.

4. Aim

The main aim stated in this work is developing and validating tools and didactic material inside the engineering field which are built through VR, AR and PDF3D technologies.

In all cases, it will be built under the principle of improvement of spatial vision abilities, learning of Graphic Design contents and better adaptation of each technology according to the engineering field where it should applied to.This implies designing learning activities following the philosophy of each one of that three technologies, implementing them in the classroom in three different groups of students of the same level, applying in everyone of them one of these technologies and studying the progress in the spatial abilities of each group for stating the influence of the tool used in the acquisition of Graphic Design knowledge.

For establishing the possible differences between these technologies, the results of learning between groups will be compared against a fourth group or control group which will use a traditional methodology, that is, not using any of the three technologies that are being studied. The specific aims are as follow:

- Divide and create learning activities that can be used through VR, AR and PDF3D.
- Propose and develop new tools and methodologies that guarantee the development of SA and the contents' acquisition in engineering students.

- Organizing and performing courses of short duration for using the tools developed with engineering students.
- Spreading the results of the proposed courses according to SA improvement, contents' acquisition and student's satisfaction degree.

5. Methodology and investigation's development

The following phases have been developed for performing the exposed work:

- Bibliography search for finding out the SA beginnings and how many influences are implied (measurements, gender difference, kinds of training, tools of training, engineering and graphic subjects' links, etc).
- Compilation of teaching material, classification and selection of exercises which may improve the spatial ability.
- For the experimental phase, computer tools and teaching material have been created.
- The procedure manuals have been created so students will follow them at each experiment study, for VR as well as AR and PDF3D.
- Data file creation for knowing the population taking part in the experimental study as well as his spatial ability and specific content levels.
- Study, design and development of knowledge surveys reached by students in every experimental study.
- Choice of spatial ability measurement tools.
- Design of usability surveys for the computer tools used in the experimental studies.
- Planning and development of experimental study.
- Data analysis.
- Investigation's conclusions.

6. Pilot study

The experience was designed from the aims and exposed methodologies in the following way:

- Every participant are freshmen in the Graphic Design subject of first course at the Industrial Technology degree of the Industrial and Civil Engineering School of the Las Palmas de Gran Canaria University.
- They were provided the spatial visualization and mental rotation measurement tests during the first class of the semester (further details to follow) which secures that no university orders were given having any influence on the SA development. Besides, we made sure that all students who underwent the knowledge level test had pre-university education.
- Series of pieces were created with 3D modeling software for performing the spatial ability training during the first three weeks of the course, so the same pieces have been used through all three technologies (VR, AR and PDF3D).
- During the training period, the students followed their theoretical classes and practice normally.
- They were administered again the spatial ability tests once the training was finished by the course's fourth week.
- A knowledge acquisition measurement exercise was designed and it was completed by all groups allowing to state learning differences between groups according to the methodology followed.
- Surveys of satisfaction and usability were fulfilled with the same contents but adapted to each one of those three technologies.

7. Material designed for training

As stated previously, all students followed the training phase with the same exercises but using three different technologies (VR, AR and PDF3D) and consequently three methodologies. In each methodology, forty exercises were created distributed in three levels of growing difficulty and similar to those used at pre-university education.

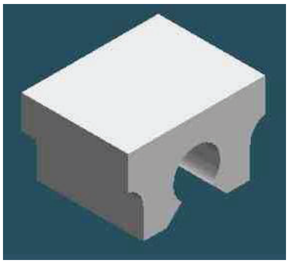

Fig. 1.Basic level's piece

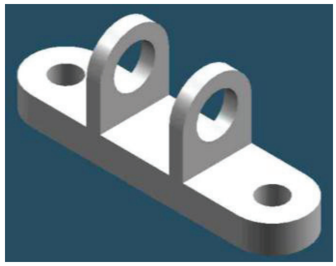

Fig. 2.Intermediate level's piece

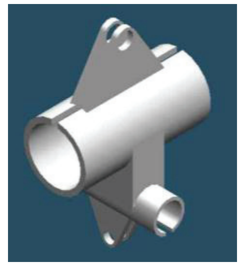

Fig. 3.Advanced level's piece.

The three methodologies aim for the same: that student gets to know the piece needless of having the real model in his own hands while having all the necessary information for sketching the piece and creating the workshop contour plan.

The exercises based on VR are uploaded to a web platform called Draw Help System (SAD). When an exercise is selected, the application shows a piece in the virtual environment allowing its manipulation (movement, rotation or change of position, etc) so the user may become aware of all its details.

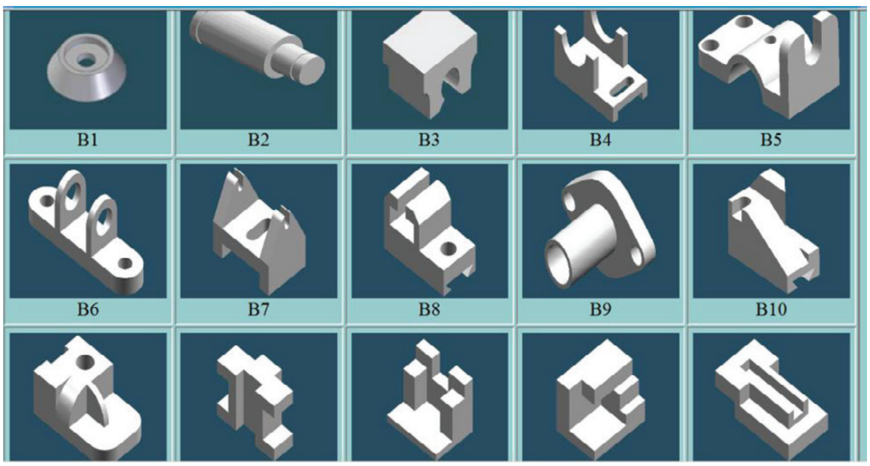

Fig. 4.SAD main window

This same exercises were transformed into U3D format used by PDF3D allowing its manipulations in an independent environment.

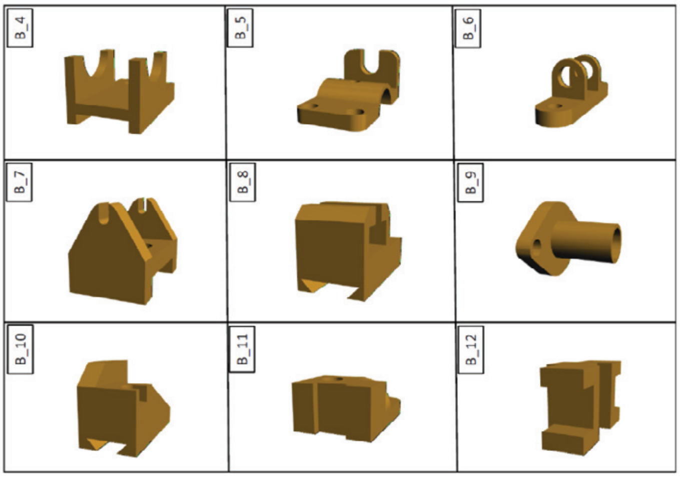

Fig 5: PDF3D interface

All exercises and pieces were adapted to the format used by the BuildAR Pro augmented reality application which allows creating scenes composed by a set of images or marks that codify a 3D model. When a scene is executed, a webcam connected to the PC recognizes an image which is related to the 3D model and shows it integrated into the real world. A 'marks book' is also created where the mark is composed by a frame and the exercise's image inside.

Fig 6: Marks book

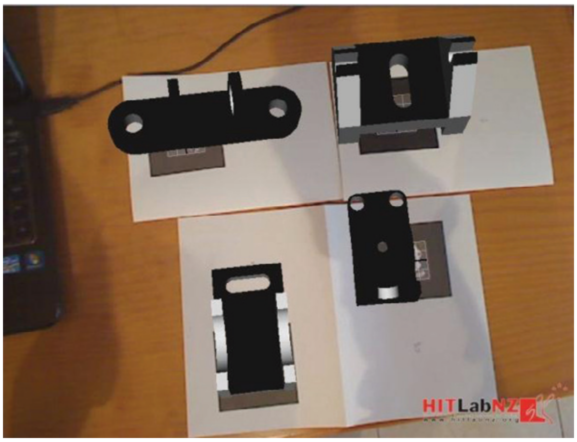

Fig 7: Rebuilding 4 marks.

8. Students' satisfaction

Bevan, (2006) mentions that in order to make reliable estimations of the satisfaction results, 8 or 10 participants are necessary and larger samples offer a more significant value of the success rate. In our study, the evaluation of the material and the software has been done by all students who have taken the courses.

The methodologies proposed have been tested on three different groups of students where each group has performed the proposed exercises through each described methodology. The students belong to the first course of the Industrial Engineering degree. The group which has performed this methodology with VR was composed by 18 students and for AR and PDF3D methodologies the groups were of 20 and 19respectively.
Once the experience is finished, they were provided with a survey for knowing the satisfaction's degree of every group about the work's methodology used. User's satisfaction has been measured using an adapted version of the QUIS Questionnaire (Harper and Norman, 1993) using a 9 point Likert scale from 1 to 9. A selection of these questions is presented in Table 1.

Table 1. Users Satisfaction measures and questions

	Group		
Question	RV	AR	PDF3D
Terrible- Wonderful	6,2	8,6	6,1
Frustrating-Satisfying	6	8,7	7,4
Dizziness-Natural environment	7,3	8,8	6
Unconfort-Confort	5,7	7,1	6
Uninteresting-Very interesting	6,2	8,6	5,5
Difilcult-Easy	8	8,5	8,4
Rigid-Flexible	7,1	7,4	6,9
Learning to operate: Difficult-Easy	6,1	8,4	7,6
System speed: Too Slow-Enough fast	8,1	8,5	8,4
Intuitive system: Not at all-Very much	7,7	8,7	7
In General Satisfaction: Low - High	6,9	8,7	6,7
Mean Values	6,8	8,4	6,9

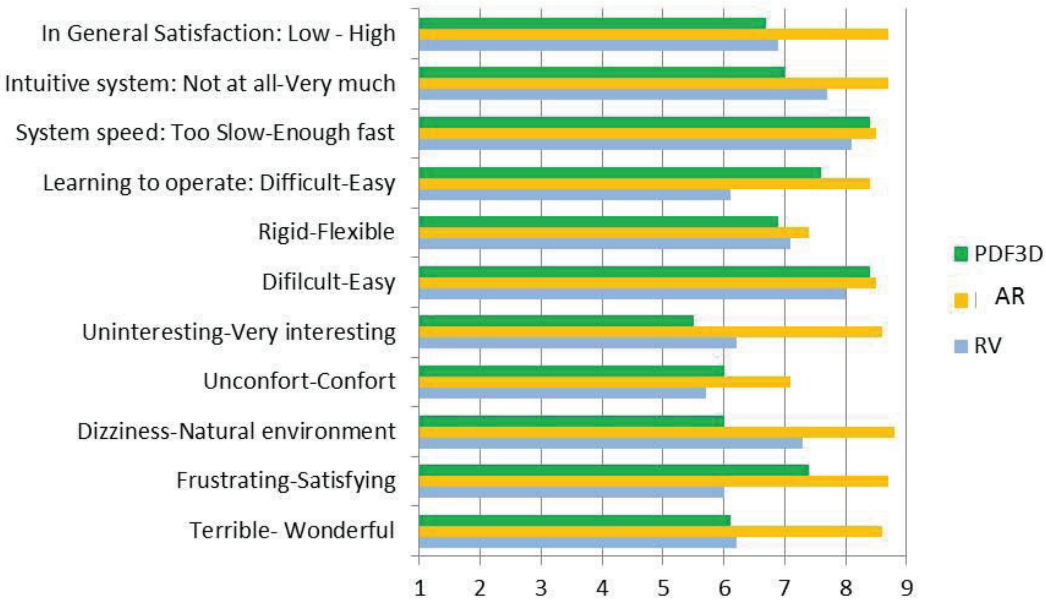

Fig. 8. Users Satisfaction measures

9. Conclusions

Technology evolution and appearance of new teaching techniques have made that some methodologies have become obsolete so they are not properly adapted to the modern trends. Teaching methods must evolve and adapt to new technologies that student are used to so learning will benefit from that.

The students are digital natives as they are used to all kinds of electronic devices and handling in many digital platforms. The traditional teaching methodology causes boredom and lack of motivation for performing the teaching activities.

The use of objects and physical models for work at the classroom are not enough for the volume of students that there is currently at those classrooms. The computer tools that allow the virtual modeling and handling of 3D objects ease the teaching tasks as any piece or figure desired is available needless to get physical models which are more expensive and take longer to create. The modeled object may be implemented in every format (virtual, augmented, PDF or any other).

We have introduced in the classrooms of an engineering degree three work methodologies based on technology tools and 3D models. Overall, the students are quite satisfied with the tools used to learn. Users enjoy the simplicity of the apps and its powerful control of tridimensional model. Specifically, those students using AR are more satisfied than those using VR and PDF showing the same values. Through data observed on site, we may state that students who trained using AR felt quite impressed and motivated by the use of a new technology which they had no previous contact as they were not aware of it so difference is due to the technology's novelty. The teachers observe that students show more participation and motivation than in groups where physical models are used, where passivity and lack of motivation during learning is noticed.

References

Adánez, G.P. and Velasco, A.D. (2002). Predicting academic success of engineering students in technical drawing from visualization test scores. *Journal of Geometry and Graphics,* 6 (1), 99–109.

Bevan, N. (2006). Practical issues in usability measurement, *Interactions*, 13, 42–43.

Harper, B. D. & Norman, K. L. (1993). Improving User Satisfaction: The Questionnaire for User Interaction Satisfaction. *Proceedingsof the 1st Annual Mid-Atlantic Human FactorsConference*, (pp. 224-228),Virginia Beach, VA.

Martín-Gutiérrez, J., Saorín, J.L., Contero, M., Alcañiz, M., Pérez-López, D.C. & Ortega, M. (2010). Design and Validation of an Augmented Reality for Spatial Abilities Development in Engineering Students. *Computer & Graphics*, 34 (1), 77-91.

Miller, C. (1996). A Historical review of applied and theoretical spatial visualization publications in engineering graphics, *Engineering Design Graphics Journal*, 60 (3), 12–33.

Rafi, A., Samsudin, K. A., & Said, C. S. (2008). Training in spatial visualization: The effects of training method and gender, *Educational Technology & Society,*11, 127-140.

Sorby, S.A. (1999). Developing 3-D spatial visualization skills, *The Engineering Design Graphics Journal,* 63 (2), 21–32.